Dynamic Liquid Cooling BoF

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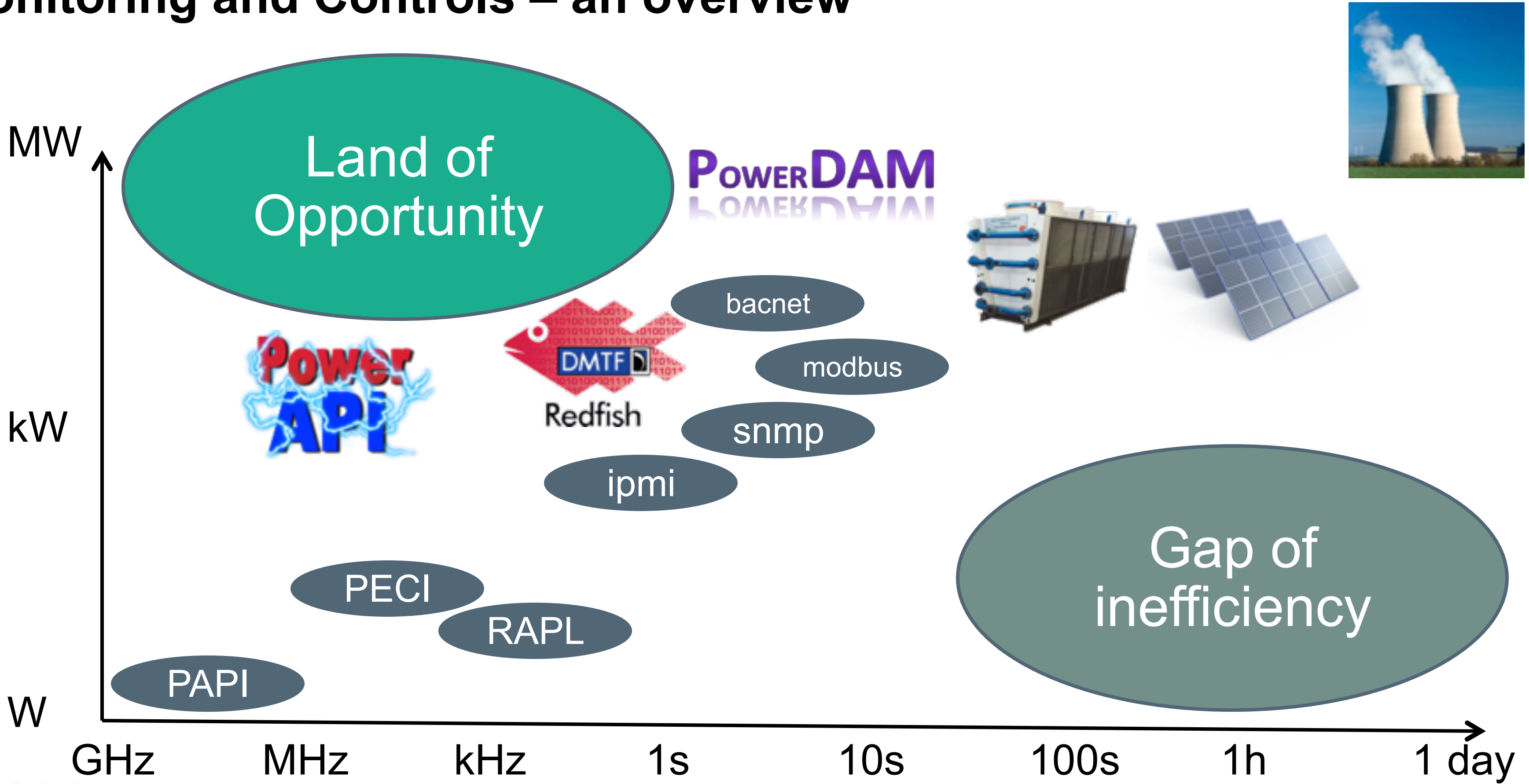
Monitoring and Controls – an overview



MW

kW

W

Land of Opportunity

PowerDAM

Power API

DMTF Redfish

bacnet

modbus

snmp

ipmi

PECI

RAPL

PAPI

Gap of inefficiency

GHz MHz kHz 1s 10s 100s 1h 1 day

Hewlett Packard Enterprise

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Apollo 8000 System Technologies

Intelligent Cooling Distribution Unit

- 320 KW power capacity
- Scaled redundancy with row level control
- Active vacuum system monitors for leaks

Dry-disconnect servers

- 100% water cooled components
- Designed for serviceability

Management infrastructure

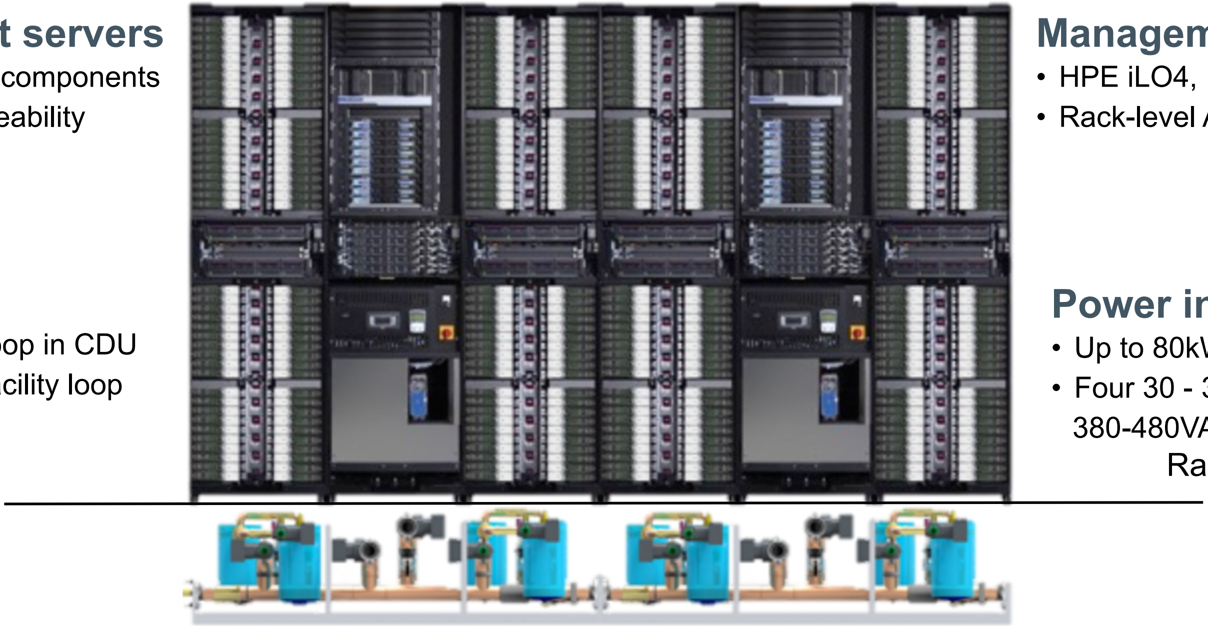
- HPE iLO4, IPMI 2.0 and DCMI 1.0
- Rack-level Advanced Power Manager

Warm water

- Closed secondary loop in CDU
- Isolated and open facility loop

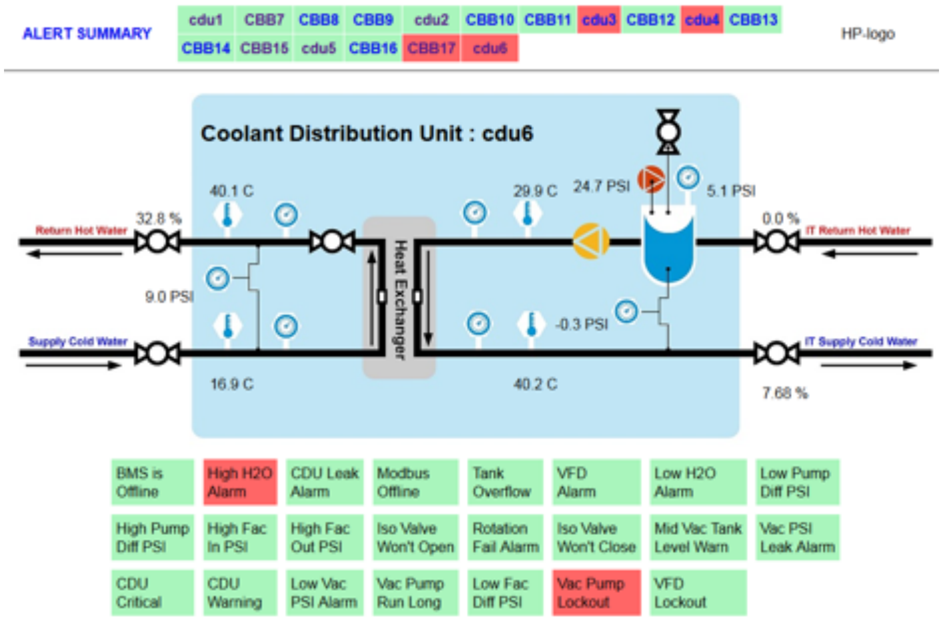
Power infrastructure

- Up to 80kW per rack
- Four 30 - 32A 3-phase 380-480VAC



Open door view of 4 f8000, redundant iCDU racks and underfloor plumbing kit

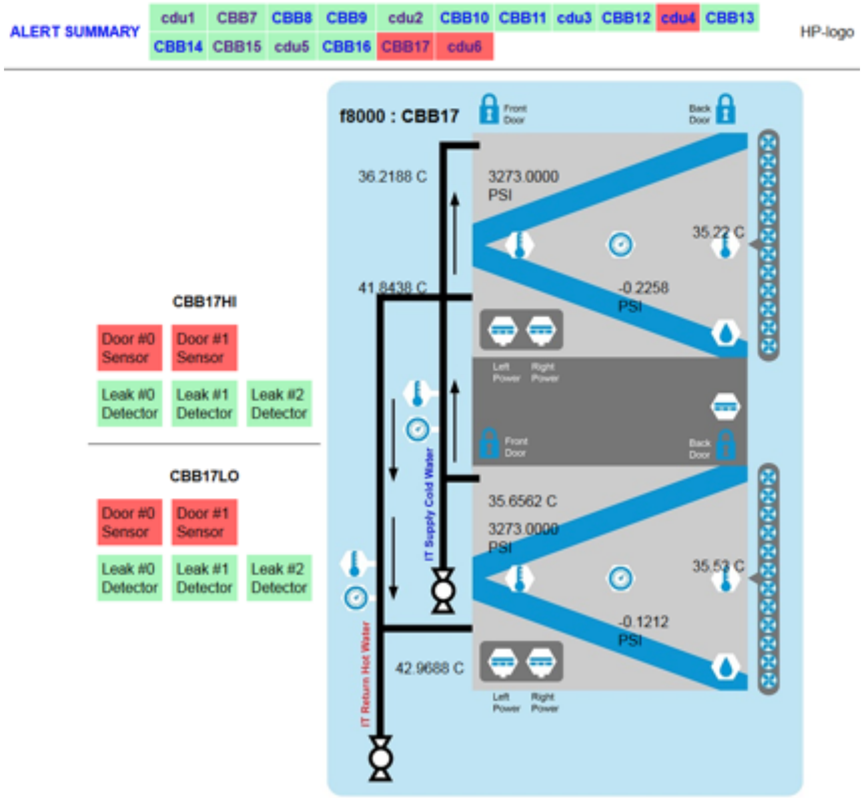
Goldstone Monitoring



ALERT SUMMARY												HP-logo
	cdu1	CBB7	CBB8	CBB9	cdu2	CBB10	CBB11	cdu3	CBB12	cdu4	CBB13	
	CBB14	CBB15	cdu5	CBB16	CBB17	cdu6						

Coolant Distribution Unit : cdu6
Return Hot Water
32.8 %
40.1 C
9.0 PSI
Supply Cold Water
16.9 C
Heat Exchanger
29.9 C
24.7 PSI
5.1 PSI
-0.3 PSI
40.2 C
0.0 %
IT Return Hot Water
IT Supply Cold Water
7.68 %

BMS is Offline	High H2O Alarm	CDU Leak Alarm	Modbus Offline	Tank Overflow	VFD Alarm	Low H2O Alarm	Low Pump Diff PSI
High Pump Diff PSI	High Fac In PSI	High Fac Out PSI	Iso Valve Won't Open	Rotation Fail Alarm	Iso Valve Won't Close	Mid Vac Tank Level Warn	Vac PSI Leak Alarm
CDU Critical	CDU Warning	Low Vac PSI Alarm	Vac Pump Run Long	Low Fac Diff PSI	Vac Pump Lockout	VFD Lockout	



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CBB17HI

Door #0 Sensor	Door #1 Sensor	
Leak #0 Detector	Leak #1 Detector	Leak #2 Detector

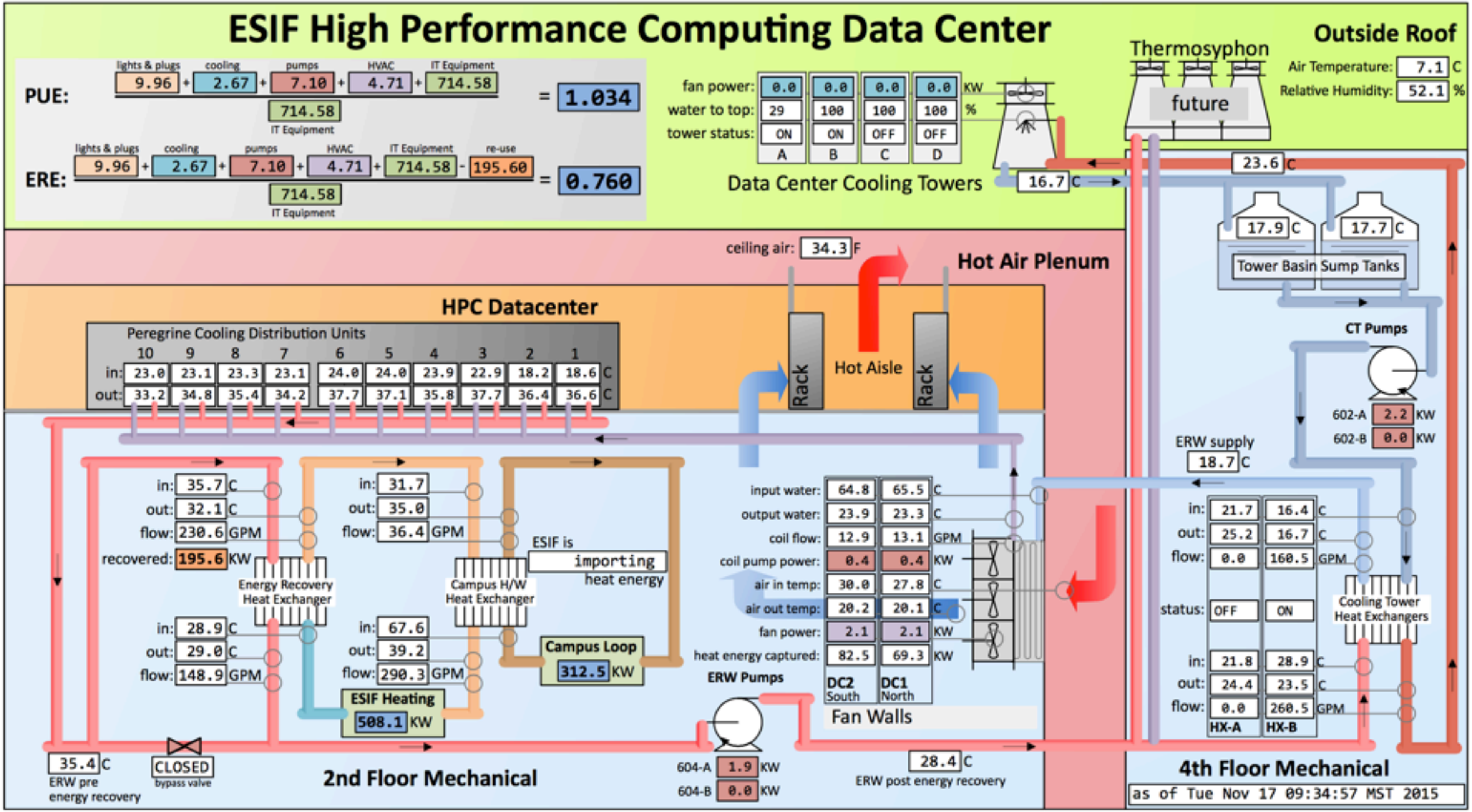
CBB17LO

Door #0 Sensor	Door #1 Sensor	
Leak #0 Detector	Leak #1 Detector	Leak #2 Detector

f8000 : CBB17
Front Door
Back Door
36.2188 C
3273.0000 PSI
35.22 C
41.8438 C
-0.2258 PSI
Left Power
Right Power
Front Door
Back Door
IT Supply Cold Water
35.6562 C
3273.0000 PSI
35.53 C
-0.1212 PSI
42.9688 C
IT Return Hot Water
Left Power
Right Power

Hewlett Packard Enterprise

ESIF High Performance Computing Data Center



PUE: lights & plugs 9.96 + cooling 2.67 + pumps 7.10 + HVAC 4.71 + IT Equipment 714.58 / 714.58 IT Equipment = 1.034

ERE: lights & plugs 9.96 + cooling 2.67 + pumps 7.10 + HVAC 4.71 + IT Equipment 714.58 - re-use 195.60 / 714.58 IT Equipment = 0.760

Data Center Cooling Towers

	A	B	C	D	
fan power:	0.0	0.0	0.0	0.0	KW
water to top:	29	100	100	100	%
tower status:	ON	ON	OFF	OFF	

Outside Roof

Air Temperature: 7.1 C

Relative Humidity: 52.1 %

23.6 C

16.7 C

Tower Basin Sump Tanks: 17.9 C, 17.7 C

CT Pumps

602-A 2.2 KW

602-B 0.0 KW

ERW supply 18.7 C

ceiling air: 34.3 F

Peregrine Cooling Distribution Units

	10	9	8	7	6	5	4	3	2	1	
in:	23.0	23.1	23.3	23.1	24.0	24.0	23.9	22.9	18.2	18.6	C
out:	33.2	34.8	35.4	34.2	37.7	37.1	35.8	37.7	36.4	36.6	C

Fan Walls

	DC2 South	DC1 North	
input water:	64.8	65.5	C
output water:	23.9	23.3	C
coil flow:	12.9	13.1	GPM
coil pump power:	0.4	0.4	KW
air in temp:	30.0	27.8	C
air out temp:	20.2	20.1	C
fan power:	2.1	2.1	KW
heat energy captured:	82.5	69.3	KW

Energy Recovery Heat Exchanger

in: 35.7 C

out: 32.1 C

flow: 230.6 GPM

recovered: 195.6 KW

in: 28.9 C

out: 29.0 C

flow: 148.9 GPM

Campus H/W Heat Exchanger

in: 31.7

out: 35.0

flow: 36.4 GPM

in: 67.6

out: 39.2

flow: 290.3 GPM

ESIF is importing heat energy

Campus Loop 312.5 KW

ESIF Heating 508.1 KW

35.4 C ERW pre energy recovery

CLOSED bypass valve

ERW Pumps

604-A 1.9 KW

604-B 0.0 KW

28.4 C ERW post energy recovery

Cooling Tower Heat Exchangers

	HX-A	HX-B	
in:	21.7	16.4	C
out:	25.2	16.7	C
flow:	0.0	160.5	GPM
status:	OFF	ON	
in:	21.8	28.9	C
out:	24.4	23.5	C
flow:	0.0	260.5	GPM

as of Tue Nov 17 09:34:57 MST 2015

Next generation ultra-efficient HPC system

In production at the DoE National Renewable Energy Laboratory (NREL)

PEREGRINE
PEREGRINE

- **The first HPC data center dedicated solely to advancing energy systems integration, renewable energy research, and energy efficiency technologies**

- **New ultra-energy-efficient, petascale HPC system**
- $1 million in annual energy savings and cost avoidance through efficiency improvements
- Petascale (one million billion calculations/ second)
- Average PUE of 1.06 or better
- Source of heat for ESIF's 185,000 square feet of office and lab spaces, as well as the walkways
- 1MW of data center power in under 1,000 sq. ft. => very energy-dense configuration

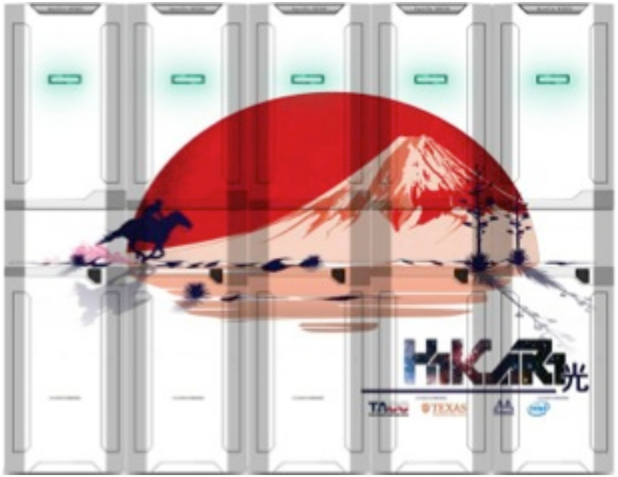
- **Designed to support NREL's mission, address research challenges, reduce risks and accelerate the transformation of our energy system**.

Hewlett Packard
Enterprise

HP Apollo 8000 Hikari Cluster

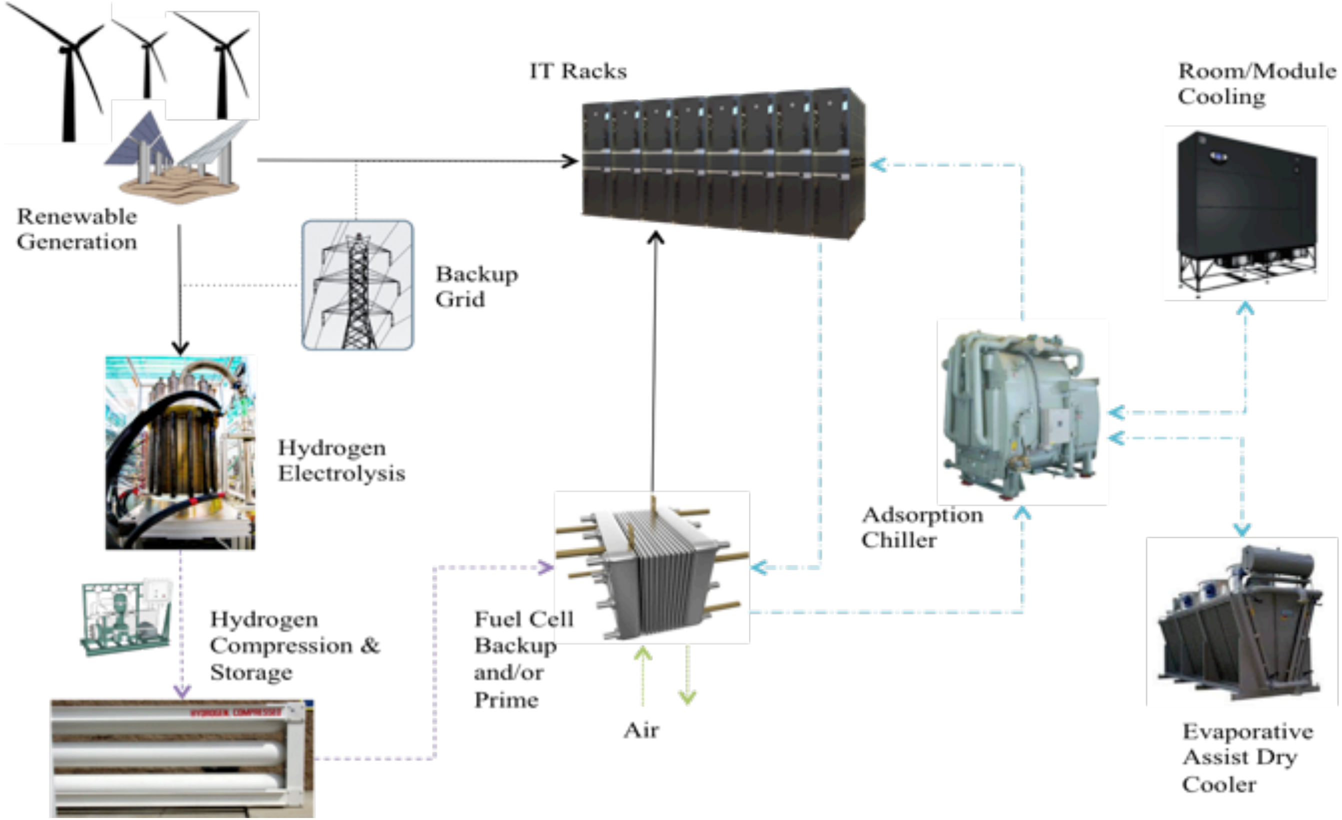
System Attributes

- 432 HP XL730f Trays (~432 Tflops)
  - HP XL730f E5-2690 Dual Socket
  - 64G HP 8GB 1Rx4 RDIMM
  - 120GB M.2 Storage
  - 1:1 EDR Fabric



Hewlett Packard
Enterprise

Towards Carbon-Free Data Centers


IT Racks
Room/Module Cooling
Renewable Generation
Backup Grid
Hydrogen Electrolysis
Adsorption Chiller
Hydrogen Compression & Storage
Fuel Cell Backup and/or Prime
Air
Evaporative Assist Dry Cooler

Source: Steve Hammond, NREL / Tahir Cader, HPe

Apollo 8000 - Most Innovative Product of 2014

2014 R&D 100

US Department of Energy
2014 Sustainability Award